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Art. IX.—*The Wet-Bulb and Kata Thermometers.*

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The ordinary thermometer which records the temperature of its immediate environment, is, as is now well known, an unreliable guide to those air conditions that influence the animal body. "It affords no measure of the rate of cooling of the human body, and is, therefore, a very indifferent instrument for indicating atmospheric conditions which are comfortable and healthy to man."[1] Of the three air factors for which the body has to make adjustments in order to keep thermostatic—namely, the temperature, water content and velocity, the thermometer records one only. The great superiority of the wet-bulb reading over the dry-bulb reading consists in this that the wet-bulb does respond to all these three variables. Though Harrington pointed out the importance of wet-bulb records, naming their indications "sensible temperatures," and actually mapped out the United States of America in wet-bulb isotherms for the month of July,[2] yet it is to Haldane[3] that we are chiefly indebted for pointing out the importance of this instrument. Haldane made some interesting recommendations concerning wet-bulb standards of temperature in mines and factories. He also pointed out that there is for the human being a critical wet-bulb temperature where the conditions are such that the body, even at rest, cannot lose its heat quick enough, and cumulative fever results. This has been confirmed by other investigators, and I may add that I have had opportunity to put the matter to the test with results that agree with Haldane's conclusions. The first great extension of the use of the wet-bulb in climatology occurred here in Australia when the Commonwealth Bureau of Meteorology, under Mr. H. A. Hunt, published maps giving wet-bulb isotherms in Australia for each month of the year 1910. After this a systematised series of wet-bulb observations was undertaken giving records of temperature in homes, offices, etc., as well as outside shade in Northern Territory, and the tropical parts of Queensland. I have had access to these records

1 Leonard Hill, O. W. Griffith and Martin Flack, The Measurement of the Rate of Heat Loss, etc. Phil. Trans. B, vol. 207, p. 184.

2 Quoted in Hann's Handbuch der Klimatologie, 1908, vol. i., p. 57.

3 J. S. Haldane. Journal of Hygiene, 1905, vol. 5, p. 494.

through the courtesy of Mr. Hunt, and find most interesting material contained in them, though to make adequate use of such data would demand more time than I am able to bestow.

The estimation of one's state of discomfort in hot weather is obviously impossible to carry out with any approach to exactness. I have tried various expedients but without result. The amount of sweat absorbed by the clothes is no guide at all, for, in this climate in summer, we have days when the human body may lose over 400 grammes[1] water per hour by evaporation and yet the skin and clothes remain dry and comfort is not greatly disturbed. A rough and ready indication which I have come to regard as the most useful is simply the clothing that is chosen as the most comfortable when the body lies in an open-meshed hammock in a good shade and at perfect rest. If such a hammock is not at hand, the upright position is, I think, best, and much preferable to resting in, say, a deck chair.[2] Judged roughly in this way, and by general feeling, I have placed wet-bulb 73° F. as an empiric standard above which truly tropical conditions arise. This wet-bulb temperature is seldom attained in the Victorian climate. A typical instance of the effect of dryness in keeping the wet-bulb down is shown in the following :—

Place.	Time.	Dry-Bulb F.	Wet-Bulb F.
Mildura	Dec. 30, 1908, 3 p.m.	110	69

contrast this with

Place.	Time.	Dry-Bulb F.	Wet-Bulb F.
Nottingham	July 29, 1911, 1 p.m.	82	73.6
Kew, London	July 29, 1911, 3 p.m.	87.7	71.3

The last-mentioned high temperature I experienced personally and can truthfully say that it exceeded in unpleasantness anything that I have felt in Melbourne or its environs.

The wet-bulb isotherms drawn by Mr. Hunt show very clearly that of all portions of Australia the worst from the climatic standpoint is the pearling coast in the north-west. In December, January and February this district is included within the 80° W.B. isotherm. I find that on December 24th, 1909, the shade wet-bulb temperature at Wyndham on this coast was 85° F. at 9 a.m. !

1 W. A. Osborne. Contributions to Physiological Climatology, Part II. J. Physiol., vol. 49, p. 133.

2 I have made some measurements of the water loss of the body in two almost successive hours in practically the same meteorological conditions, the first hour in a hammock, the second in a deck chair, and found that in the latter case the water loss was considerably increased in each instance owing to the impeded evaporation—the water given off by the skin was of course to be found in the fabric of the deck chair and in the clothing with which it was in contact.

In the course of observations, I began to detect some discrepancies between the wet-bulb reading and the state of discomfort of the body. The most striking of these occurs when a hot day with strong north wind and clear sky undergoes a "change." The sky becomes overcast and the wind drops. There may or may not be electrical disturbance. At this time the air conditions may become most oppressive, and sweating may be very copious on exertion. Now, in all the observations I have made in five summers, I have only noted two occasions in which the wet-bulb rose with the overcasting of the sky and the drop in the wind. In all other cases the wet-bulb, like the dry-bulb, fell. I, therefore, came to the conclusion that the wet-bulb is not sufficiently sensitive to air currents. Experiments on the evaporation from the skin and from an evaporimeter confirmed me in this view.[1] I, therefore, devised a wet-bulb thermometer, having its bulb within a cylindrical gauze cage open at the bottom but otherwise covered with cloth. At the suggestion of Professor Roaf bolting cloth of standard mesh was used for this latter purpose. These "jacketed wet-bulb thermometers" manifested a much better response to air movement, and when tested in a "change," usually gave a rise in temperature. Further experience, however, brought to the light new difficulties. The cloth was apt to get greasy, and to shrink, so I fell back on various porous substances. The same trouble with grease still pursued me, and, most annoying of all, I found that the slightest shift in the position of the bulb made a change in the height of the column, and that it was practically impossible to obtain two jacketed thermometers that gave the same reading. This particular effort, then, which has cost me some considerable time I have been compelled to give up, as I do not see how standardisation can be effected.

The Kata-thermometer of Leonard Hill works on a different principle. Here the time of cooling of a large wet-bulb through a range of 10° F. (from 100° F. to 90° F.) is taken, and the cooling power of the air calculated in terms of millicalories per cm^2 per second. I have had just one summer's experience with three of these instruments, one of them having been kindly sent to me by Professor Leonard Hill who had worked out its special factor.[2] The Kata-thermometer certainly indicates well the onset of oppressive thunder weather and therein manifests its superiority to the wet-bulb. But I soon discovered that in its present form it is somewhat too sensitive to air currents, at any rate in hot, dry weather. The following

1 W. A. Osborne. Contributions to Physiological Climatology, loc. cit.

2 A kerosene tin can be employed with very fair results for obtaining the reading in still air.

data, expressed in seconds, for the cooling of a wet Kata from 100° F. to 90° F., may be taken as illustrating this. Date—Dec. 28th, 1915.

Time.	Dry-Bulb F.	Wet-Bulb F.	Kata Time.	Wind.
0–20 p.m.	94.3	68.7	38″	slight
0–30 p.m.	94.3	68.7	41″	slight
0–35 p.m.	94.5	68.8	43″	very slight
1–45 p.m.	98.7	70	34″	gust

I found, indeed, that it was easy to obtain, especially, as I have said, in hot, dry weather with unsteady wind, greater variations in the wet Kata reading than it was possible that the state of the body could parallel. In fact, theory would suggest that the bulb of the Kata should approximate in size, shape and water equivalent to the human body if correct values are to be obtained. Of course, a series of readings in fairly quick succession could be taken with the present Kata, and the average computed, but this would be tedious. On the other hand, in calm weather, also when the wind was moderately steady, I obtained consistent readings.

More experience is necessary before I can venture to come to a conclusion. Yet, so far as my observations go, I feel that for estimating air conditions in mines and buildings, and possibly sheltered outside places where variations in air velocity are not of much magnitude, the Kata-thermometer is the better instrument. Very probably, too, it could be used profitably in those tropic areas where calm weather is the rule. But for ordinary climatological purposes I still feel that the wet-bulb record is of high value.